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UNITED STATES DEPARTMENT OF COMMERCE  
PATENT AND TRADEMARK OFFICE  
PATENT EXAMINATION BRANCH

In re Application of:	)	
Xianglin WANG et al.	)	Examiner: Torres, Jose
	)	
For: METHOD AND APPARATUS FOR	)	Group Art Unit: 2624
IMAGE INTERPOLATION BASED	)	
ON ADAPTIVE POLYPHASE	)	Confirmation No.: 7881
FILTERS	)	
	)	Response to Office Action
Appln. No.: 10/697,358	)	dated October 17, 2007
	)	
Filed:       October 30, 2003	)	
	)	

**RESPONSE TO FINAL OFFICE ACTION OF OCTOBER 17, 2007**  
**AND REQUEST TO WITHDRAW FINALITY OF THE OFFICE ACTION**

MS AF  
Commissioner of Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

This is a Response to the final Office Action dated October 17, 2007. Reconsideration and allowance of the claims is respectfully requested in view of the following amendments and remarks. Please charge any deficit or credit any surplus to our Deposit Account No. 01-1960. A duplicate copy of this page is enclosed for this purpose.

**Amendments to the Claims** begin on page 2 of this paper.

**Remarks** begin on page 20 of this paper.

**Amendments to the Claims:**

This listing of claims replaces all prior versions of the claims in the patent application:

1. (Previously presented) A method of interpolating image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising the steps of:
  - (a) providing a first filter having a sharp interpolation characteristic;
  - (b) providing a second filter having a smooth interpolation characteristic;
  - (c) interpolating a selected image position in the image using the first filter to generate a sharp interpolation output value;
  - (d) interpolating the selected image position in the image using the second filter to generate a smooth interpolation output value;
  - (e) calculating a different weighting coefficient for the output of each filter by estimating a high frequency level at the interpolated selected image position and calculating the weighting coefficients based on the estimated image high frequency level; and
  - (f) selectively combining the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image.
2. (Canceled).

3. (Currently amended) A method of interpolating image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising the steps of:

- (a) providing a first filter having a sharp interpolation characteristic;
- (b) providing a second filter having a smooth interpolation characteristic;
- (c) interpolating a selected image position in the image using the first filter to generate a sharp interpolation output value;
- (d) interpolating the selected image position in the image using the second filter to generate a smooth interpolation output value;
- (e) calculating a different weighting coefficient for the output of each filter by estimating a high frequency level at the interpolated selected image position and calculating the weighting coefficients based on the estimated image high frequency level; and
- (f) selectively combining the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image

The method of claim 1, wherein the weighting coefficient  $\alpha$  for the first filter output is calculated according to the relation:

$$\alpha = \min(1, \max(0, (\varphi - T_1)/(T_2 - T_1)))$$

wherein  $\varphi$  is the image high frequency level estimated for the given interpolation position,  $T_1$  and  $T_2$  are two pre-determined threshold values where  $T_2 > T_1 \geq 0$ ; and

the weighting coefficient for the second filter output is  $(1 - \alpha)$ .

4. (Previously presented) The method of claim 1, wherein the interpolation output value  $q$  for the selected image position is according to the relation:

$$q = r * \alpha + s * (1 - \alpha)$$

wherein  $\alpha$  and  $(1 - \alpha)$  are the weighting coefficients for the first and second filters, respectively ( $0 \leq \alpha \leq 1$ ), and  $r$  and  $s$  are the filter output values from the first and second filters, respectively.

5. (Original) The method of claim 1, wherein:

the first filter comprises a polyphase filter; and  
the second filter comprises a polyphase filter.

6. (Original) The method of claim 5, wherein:

the first filter comprises a one dimensional FIR polyphase filter; and  
the second filter comprises a one dimensional FIR polyphase filter.

7. (Original) The method of claim 5, wherein the two polyphase filters have the same length.

8. (Original) The method of claim 5, wherein each of the polyphase filters comprises a  $N$ -tap  $M$ -phase polyphase filter.

9. (Original) The method of claim 8, wherein for arbitrary or variable interpolation ratios,  $M$  has a value of 10 or larger.

10. (Original) The method of claim 8, wherein  $N$  can be either an odd or an even number value.

11. (Original) The method of claim 5, wherein the two filters are low-pass filters, such that the first filter has a sharp frequency transition band and the second filter has a smooth frequency transition band.

12. (Original) The method of claim 8, wherein:  
calculating the weighting coefficient for each of the two filters further includes the steps of: estimating the image high frequency level at the selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level; and

the image high frequency level at the selected image position is estimated based on the image high frequency components measured at original image pixels neighboring the selected image position.

13. (Original) The method of claim 12, wherein the image high frequency component at the original image pixels is measured using a high-pass filtering process.

14. (Original) The method of claim 13, wherein the image high frequency component at the original image pixels is measured using a high-pass FIR filter.

15. (Previously presented) A method of interpolating image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising the steps of:

providing a first filter having a sharp interpolation characteristic;

providing a second filter having a smooth interpolation characteristic;

each of the filters comprises a  $N$ -tap  $M$ -phase polyphase filter;

interpolating a selected image position in the image using the first filter to generate a sharp interpolation output value;

interpolating a selected image position in the image using the second filter to generate a smooth interpolation output value;

calculating a weighting coefficient for the output of each filter by estimating the image high frequency level at the selected image position based on image high frequency components measured at original image pixels neighboring the selected image position, and calculating the weighting coefficients based on the estimated image high frequency level;

selectively combining the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image;

wherein the image high frequency component  $\phi_i$  at each of the original image pixels is measured according to the relation

$$\phi_i = |p_i - 0.5 * (p_{i-1} + p_{i+1})|$$

wherein  $p_i$  is original image pixel value where image high frequency component is to be measured, and  $p_{i-1}$  and  $p_{i+1}$  are original image pixel values of the neighboring pixels.

16. (Original) The method of claim 15, wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

$$\varphi = \sum_{i=-\frac{N}{2}+1}^{\frac{N}{2}} (0.5 * (f_{-i+1}^j + g_{-i+1}^j) * \phi_i)$$

wherein  $\phi_i$ ,  $i = -\frac{N}{2} + 1, \dots, 0, \dots, \frac{N}{2}$  are the image high frequency components calculated at the original image pixels that are within the filtering range of interpolation to the selected image position,  $f_i^j$  and  $g_i^j$  are filter coefficients of sub-filters  $f^j$  and  $g^j$  for the first filter and the second filter, respectively, and  $j$  is the interpolation phase for the selected image position.

17. (Original) The method of claim 12, wherein the image high frequency level at the selected image position is estimated based on the image high frequency components calculated at two original image pixels closest to the selected image position.

18. (Previously presented) A method of interpolating image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising the steps of:

- providing a first filter having a sharp interpolation characteristic;
- providing a second filter having a smooth interpolation characteristic;
- each of the filters comprises a  $N$ -tap  $M$ -phase polyphase filter;
- interpolating a selected image position in the image using the first filter to generate a sharp interpolation output value;
- interpolating a selected image position in the image using the second filter to generate a smooth interpolation output value;
- calculating a weighting coefficient for the output of each filter by estimating the image high frequency level at the selected image position based on image high frequency components measured at original image pixels neighboring the selected image position, and calculating the weighting coefficients based on the estimated image high frequency level;
- selectively combining the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image;
- wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

$$\varphi = d_1 * \phi_0 + d_0 * \phi_1$$

wherein  $\phi_0$  and  $\phi_1$  are the image high frequency components calculated at the two closest original image pixels,  $d_0$  and  $d_1$  are the distances between the selected interpolation position and the two closest original image pixel and the distance between two neighboring original image pixels is assumed to be 1, such that  $d_0 + d_1 = 1$ .

19. (Original) The method of claim 12, wherein the image high frequency level at the selected image position is estimated based on the image high frequency component measured at original image pixels that are within the filtering range of interpolation to the selected image position.

20. (Previously presented) A method of interpolating image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising the steps of:

- providing a first filter having a sharp interpolation characteristic;
- providing a second filter having a smooth interpolation characteristic;
- each of the filters comprises a  $N$ -tap  $M$ -phase polyphase filter;
- interpolating a selected image position in the image using the first filter to generate a sharp interpolation output value;
- interpolating a selected image position in the image using the second filter to generate a smooth interpolation output value;
- calculating a weighting coefficient for the output of each filter by estimating the image high frequency level at the selected image position based on image high frequency

components measured at original image pixels neighboring the selected image position, and calculating the weighting coefficients based on the estimated image high frequency level;

selectively combining the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image; and

wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

$$\varphi = \sum_{i=-\frac{N}{2}+1}^{\frac{N}{2}} (0.5 * (f_{-i+1}^j + g_{-i+1}^j) * \phi_i)$$

wherein  $\phi_i$ ,  $i = -\frac{N}{2} + 1, \dots, 0, \dots, \frac{N}{2}$  are the image high frequency

components calculated at the original image pixels that are within the filtering range of interpolation to the selected image position,  $f_i^j$  and  $g_i^j$  are the filter coefficients of sub-filters  $f^j$  and  $g^j$  for the first filter and the second filter, respectively, and  $j$  is the interpolation phase for the selected image position.

21. (Previously presented) An interpolation system that interpolates image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising:

- (a) a first filter having a sharp interpolation characteristic, the first filter interpolating a selected image position in the image to generate a sharp interpolation output value;
- (b) a second filter having a smooth interpolation characteristic, the second filter interpolating the selected image position in the image to generate a smooth interpolation output value;
- (c) a controller that calculates a weighting coefficient for the output of each filter by estimating a high frequency level at the interpolated selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level; and
- (d) a combiner that selectively combines the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image.

22. (Canceled).

23. (Currently amended) An interpolation system that interpolates image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising:

- (a) a first filter having a sharp interpolation characteristic, the first filter interpolating a selected image position in the image to generate a sharp interpolation output value;

(b) a second filter having a smooth interpolation characteristic, the second filter interpolating the selected image position in the image to generate a smooth interpolation output value;

(c) a controller that calculates a weighting coefficient for the output of each filter by estimating a high frequency level at the interpolated selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level; and

(d) a combiner that selectively combines the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image

~~The system of claim 21, wherein the controller calculates the weighting coefficient  $\alpha$  for the first filter output according to the relation:~~

$$\alpha = \min(1, \max(0, (\varphi - T_1)/(T_2 - T_1)))$$

wherein  $\varphi$  is the image high frequency level estimated for the given interpolation position,  $T_1$  and  $T_2$  are two pre-determined threshold values where  $T_2 > T_1 \geq 0$ , whereby that the weighting coefficient for the second filter output is  $(1 - \alpha)$ .

24. (Previously presented) The system of claim 21, wherein the combiner determines the interpolation output value  $q$  for the selected image position according to the relation:

$$q = r * \alpha + s * (1 - \alpha)$$

wherein  $\alpha$  and  $(1 - \alpha)$  are the weighting coefficients for the first and second filters, respectively ( $0 \leq \alpha \leq 1$ ), and  $r$  and  $s$  are the filter output values from the first and second filters, respectively.

25. (Original) The system of claim 21, wherein:

the first filter comprises a polyphase filter; and  
the second filter comprises a polyphase filter.

26. (Original) The system of claim 25, wherein:

the first filter comprises a one dimensional FIR polyphase filter; and  
the second filter comprises a one dimensional FIR polyphase filter.

27. (Original) The system of claim 25, wherein the two polyphase filters have the same length.

28. (Original) The system of claim 25, wherein each of the polyphase filters comprises a  $N$ -tap  $M$ -phase polyphase filter.

29. (Original) The system of claim 28, wherein for arbitrary or variable interpolation ratios,  $M$  has a value of 10 or larger.

30. (Original) The system of claim 28, wherein  $N$  can be either an odd or an even number value.

31. (Original) The system of claim 25, wherein each of the two filters comprises a low-pass filter, such that the first filter has a sharp frequency transition band and the second filter has a smooth frequency transition band.

32. (Original) The system of claim 28, wherein:  
the controller calculates the weighting coefficient for each of the two filters by estimating the image high frequency level at the selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level, such that the image high frequency level at the selected image position is estimated based on the image high frequency components measured at original image pixels neighboring the selected image position.

33. (Original) The system of claim 32, wherein the image high frequency component at the original image pixels is measured using a high-pass filtering process.

34. (Original) The system of claim 33, wherein the image high frequency component at the original image pixels is measured using a high-pass FIR filter.

35. (Previously presented) An interpolation system that interpolates image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising:

a first filter having a sharp interpolation characteristic, the first filter interpolating a selected image position in the image to generate a sharp interpolation output value;

a second filter having a smooth interpolation characteristic, the second filter interpolating the selected image position in the image to generate a smooth interpolation output value;

wherein each of the first and second filters comprises a polyphase filter, and each of the polyphase filters comprises a  $N$ -tap  $M$  phase polyphase filter;

a controller that calculates a weighting coefficient for the output of each filter by estimating the image high frequency level at the selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level such that the image high frequency level at the selected image position is estimated based on image high frequency components measured using a high-pass filtering process at original image pixels neighboring the selected image position; and

a combiner that selectively combines the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image;

wherein the image high frequency component  $\phi_i$  at each of the original image pixels is measured according to the relation:

$$\phi_i = |p_i - 0.5 * (p_{i-1} + p_{i+1})|$$

wherein  $p_i$  is original image pixel value where image high frequency component is to be measured, and  $p_{i-1}$  and  $p_{i+1}$  are values of its neighboring pixels.

36. (Original) The system of claim 35, wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

$$\varphi = \sum_{i=-\frac{N}{2}+1}^{\frac{N}{2}} (0.5 * (f_{-i+1}^j + g_{-i+1}^j) * \phi_i)$$

wherein  $\phi_i$ ,  $i = -\frac{N}{2} + 1, \dots, 0, \dots, \frac{N}{2}$  are the image high frequency

components calculated at the original image pixels that are within the filtering range of interpolation to the selected image position,  $f_i^j$  and  $g_i^j$  are filter coefficients of sub-filters  $f^j$  and  $g^j$  for the first filter and the second filter, respectively, and  $j$  is the interpolation phase for the selected image position.

37. (Original) The system of claim 32, wherein the image high frequency level at the selected image position is estimated based on the image high frequency components calculated at two original image pixels closest to the selected image position.

38. (Previously presented) An interpolation system that interpolates image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising:

a first filter having a sharp interpolation characteristic, the first filter interpolating a selected image position in the image to generate a sharp interpolation output value;

a second filter having a smooth interpolation characteristic, the second filter interpolating the selected image position in the image to generate a smooth interpolation output value;

wherein each of the first and second filters comprises a polyphase filter, and each of the polyphase filters comprises a  $N$ -tap  $M$  phase polyphase filter;

a controller that calculates a weighting coefficient for the output of each filter by estimating the image high frequency level at the selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level such that the image high frequency level at the selected image position is estimated based on image high frequency components measured at original image pixels closest to the selected image position;

a combiner that selectively combines the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image;

wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

$$\varphi = d_1 * \phi_0 + d_0 * \phi_1$$

wherein  $\phi_0$  and  $\phi_1$  are the image high frequency components calculated at the two closest original image pixels,  $d_0$  and  $d_1$  are the distances between the selected

interpolation position and the two closest original image pixels, the distance between two neighboring original image pixels is assumed to be 1, such that  $d_0 + d_1 = 1$ .

39. (Original) The system of claim 32, wherein the image high frequency level at the selected image position is estimated based on the image high frequency component measured at original image pixels that are within the filtering range of interpolation to the selected image position.

40. (Previously presented) An interpolation system that interpolates image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising:

a first filter having a sharp interpolation characteristic, the first filter interpolating a selected image position in the image to generate a sharp interpolation output value;

a second filter having a smooth interpolation characteristic, the second filter interpolating the selected image position in the image to generate a smooth interpolation output value;

wherein each of the first and second filters comprises a polyphase filter, and each of the polyphase filters comprises a  $N$ -tap  $M$  phase polyphase filter;

a controller that calculates a weighting coefficient for the output of each filter by estimating the image high frequency level at the selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level such that the image high frequency level at the selected image position is

estimated based on image high frequency components measured at original image pixels neighboring the selected image position;

a combiner that selectively combines the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image;

wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

$$\varphi = \sum_{i=-\frac{N}{2}+1}^{\frac{N}{2}} (0.5 * (f_{-i+1}^j + g_{-i+1}^j) * \phi_i)$$

wherein  $\phi_i$ ,  $i = -\frac{N}{2} + 1, \dots, 0, \dots, \frac{N}{2}$  are the image high frequency components calculated at the original image pixels that are within the filtering range of interpolation to the selected image position,  $f_i^j$  and  $g_i^j$  are the filter coefficients of sub-filters  $f^j$  and  $g^j$  for the first filter and the second filter, respectively, and  $j$  is the interpolation phase for the selected image position.